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Design of a Machine for Testing Commutators and Brushes

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THE DESIGN AND CONSTRUCTION OF A MACHINE FOR TESTING COMMUTATORS AND BRUSHES

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

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COMMUTATOR AND BRUSH TESTING MACHINE.

The theory of commutation has been much studied and written upon, but there has been little written upon its practical side, the testing of brushes and commutators and direct methods of measuring the current in the armature conductors during the short circuiting of the coils by the brushes. These all have direct bearing upon each other, as the current in the coils depends largely upon the contact resistance of the brushes during short circuiting.

It is my purpose in this paper to bring out the design of a machine for the determination of the contact resistances of brushes and commutators and the laws under which it varies, and the coefficient of friction of the brushes and commutators and the laws of its variation, and also a method of measuring the current in the brushes and armature coils during the instant of shortcircuiting of the coil by the brushes.

At the Electrical Show a machine was exhibited by the Purdue University for testing brushes. This machine consisted of a commutator mounted on a bearing without an armature driven by a motor to which it was direct connected. Bearing on the commutator were two brushes. The commutator had two shortcircuiting rings around it. The current entered the commutator through one of the brushes and then passes down the segment to the ring and through the ring to the segments under the other brush and out through this brush. The resistance of the contact was probably calculated from the current and the potential drop over the brushes, less the drop of the conductors. With this apparatus the contact resistances of various samples of brushes could be determined, and also the effect that peripheral speed, brush pressure, and temperature have on the contact resistance can be det-

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ermined.

This machine also had facilities for measuring the coefficient of friction of brushes. Between the commutator shaft and the motor drive was arranged a dynamometer by which the torque of the commutator could be measured. The torque of the commutator is composed of the friction of the bearings the windage, and the brush friction. The first two can be determined by raising the brushes from the commutator and making a run and determine the torque torque necessary to drive the commutator at various speeds. This can be plotted as a speed-torque curve and used in determining the bearing friction and windage loss. Since two of the three quantities that make up the driving torque of the commutator are known, the third can be determined from the difference of the whole and these two, and the coefficient of friction can be calculated from the torque of the brushes. I have no data as to the sensitiveness of this machine for this purpose but believe that it can be improved upon in a number of ways as can be seen from my design.

Mr. K.C.Nandi in a paper in the Electrical Engineer (Jan 5 1906) describes a method of testing the brush resistance on the machine. He removes the fields of the machine and rotated the armature with a current flowing in it, and measured the drop over the brushes, from this he deducted the armature resistance to obtain the contact resistance. This method does not appeal to me very much as it is only at best an approximate method. The resistance of the armature is not very constant with a current flowing through it as the current will cause a rise in the temperature and thus a change in the resistance. This resistance would not be very easy to determine because there are two paths through the armature and the resistance is not constant with every position of the brushes on the commutator. The author stated that effect of the armature revolving in the earth's magnetic field was negligible.

Much of my design has been suggested by a paper by F.C.Clark, 'Some Commutation Phenomena of Direct Current Machinery,' in which he gives considerable data and the methods by which the data was obtained. In my work I have followed Mr. Clarks suggestions and have tried to correct the faults that he found with his apparatus.

This machine is designed for the purpose of determining the quality of brushes and materials for commutators. In order to determin these qualities and the laws under which they vary, it is necessary to keep all the conditions constant and to vary that one condition through its range and note the effect on the change.

The first quality of brushes this machine is designed to determineis the contact resistance between the brush and the commutator. This varies first, with the materials of the brush and the material of the commutator. The contact resistance also varies with the peripheral speed of the commutator the pressure of the brush on the commutator and the temperature of the brush at the point of contact.

The second quality to be determined is the coefficient of friction between the commutator and the brush. This varies with the material of which the brush and the commutator are made, and also the peripheral speed of the commutator with reference to the brushes, the pressure of the brushes on the commutator and the temperature of the brush may have some effect on the coefficient of friction.

The machine as designed for this purpose consists of a commutator mounted upon a bearing. The bearing consists of a bed plate which is shown in Plate 1, two pedestals which are shown in Plate 2, and linings for the bearings which are shown in Plate 3 and consist of two bronze bushings. The bed plate is made of cast iron and in order to make it light and strong the material

is thin and is reinforced by ribs one running down the middle lengthwise and three others running cross wise. The settings for the pedestals is raised above the other material for strength and also to facilitate planing. The pedestals and caps are also made of cast iron and are made as light and strong as possible. The caps to the pedestals are secured by four 9/16" cap bolts and the return of the cap is further secured by dowld in the pedestals which extend into the cap. The lining to the bearing is a cast bronzebushing. The bronzewas used for bearing for its atrength as one of the bushings carries the brush spider. The lubrication of the bearing is by means of a chane which dips down into an oil reservoir in the pedastal below the bearing. The oil is asmitted to the bearing through a hole in the cap and there is a tap in the lower pare of the reservoir through which the oil can be emptied from the reservoir.

The brush spider which is shown in Plate 4 is a special feature of the design. The brush spider is mounted upon ball bearings, which enables the spider to rotate about the axis of the commutator freely, but at the same time the spider is rigid to motion ~~te~~ in any other direction. This construction enables us to measure the torque of the trushes on the commutator from the torque on the brush spider, and at the same time the spider will be rigid to motion in any other direction enough so that the pressure of the brushes on the commutator can be regulated and adjusted accurately. The friction of the bearing will be so small as to be neglegable. The construction of the brush spider and ball bearing race is shown in Plate 4. The ball bearing race consists of four parts, two sleeves and two rings. The bearing consists of two races at a distance of two and one halg inches from each other and the races have four points of contact. The inner part of the race consists of a sleeve with two grooves cut in it. The sleeve was of mach-

inest steel and after it was machined it was case hardened and forced on to the projecting end of one of the bronze bushings and then ground by means of an emery wheel. The outer half of the race was split in three parts at the center of the two races in order that the balls could be sliped into the races. These sleeves and rings were made of machine steel and were case hardened and ground after being machined. The outer half was secured to the brush spider, the sleeve being made a close fit and then secured by the means of set screws and the rings secured in place by means of screws, eight being used on each ring. The ends of the brush spider was so made that the brush arms can be moved in or out and the distance between the brush holder and the commutator made any desired distance.

The brush arm and details of its construction are shown on Plate 5. The brush arm is made of brass and is insulated from the brush spider by means of hard rubber washers and bushings the details of which are shown on the same plate. The brush arm is so constructed that it will carry different sizebrush holders. It is made in two parts, one which fastend to the spider and the other projects and carries the brush holder. The latter is made with a thread on one end which screws into the part which fastens on to the spider.

The brush holder of which we have three sizes are not of special construction but are a brush which was at one time used on the Fort Wayne Electric Co.'s machines. It is shown in detail in Plate 6. The principle feature of this style of brush is that the motion of the spring which holds the brush against the commutator is in the same direction as the brush itself and this spring can be calibrated and the pressure of the brush can be measured by the position of the spring instead of measuring it directly. The brush is also arranged so that it can be fed to the commutator at any angle with or

against the direction of rotation of the commutator.

The whole is arranged with a cover which is placed over the commutator and the brush spider. With the cover in place a heating coil can be placed inside and the temperature can be brought to and kept at any value desired. The volume of the commutator is do great that the current does not affedt the temperature except at a very slight extent so that variation in temperature have to be obtained by other means.

The means of driving the commutator is by means of a variable speed motor which is belt connected to the shaft of the commutator. The bearings are very generously designed so that it was not necessary to make the bearing on the belted end any larger than the other. The bearings are very carefully alined and finished so that the commutator will run smoothly at high speeds without vibration and end play.

I have gone over the design of the machine, and I will now endever to go over the process of testing brushes and commutators and to point out special features in the design

In determination of the effect of the variation of speed upon the contact resistance the drop over the brushes is measured as near to the point of contact of the brushes as possible, the temperature of the commutator being allowed to rise until constant and the brush pressure being kept constant, and the speed being varied from a minimum to a maximum.

The next thing to be determined is the variation of the contact resistance with the brush pressure. The temperature is allowed to reach a constant value and the peripheral speed is kept constant while the brush pressure is varied. The brush pressure can be varied nicely and accurately by means of the calibrated brush holder. The angle at which the brush is fed to the commutator can also be given values and the effect of this also determined.

The last variation to be determined is that of the contact resistance and the temperature of the commutator and the brushes. The peripheral speed and the brush pressure is kept constant, while the temperature of the contact is varied by placing on the hood and heating the air until the temperature of the commutator is at the proper value, a method used by Mr. Clark was to place a number of incandescent lamps near the commutator and to heat the commutator by means of radiation, until the desired temperature was reached.

For the measurement of the coeffiecient of friction of the brushes on the commutator we have introduced a new method, by which the friction can be measured directly and from this the coefficient can be calculated. As stated above the brush spider is mounted upon ball bearings, which allow it move freely about the axis of the commutator. The friction is measured by measuring the pull of the spider on a spring balance. The only errors introduced are in the friction of the bearing which should be negligible, if care is used in the other adjustments.

The first determination to make is the determination of the effect of the peripheral speed upon the coefficient of friction. This is done by operating the commutator at different speeds and keeping the brush pressure constant. The temperature of the commutator may have some effect on the coefficient of friction so this should be kept constant.

The effect of the brush pressure on the coefficient of friction can then be determined. The temperature and peripheral speed of the commutator are kept constant. The effect of the angle of the brush to the commutator can also be determined. It also makes a difference whether the pressure of the brush is with or against the direction of rotation.

Very little is known of the shape of the current wave in an armature conduction, especially at the point of the shortcircuiting of the coil by

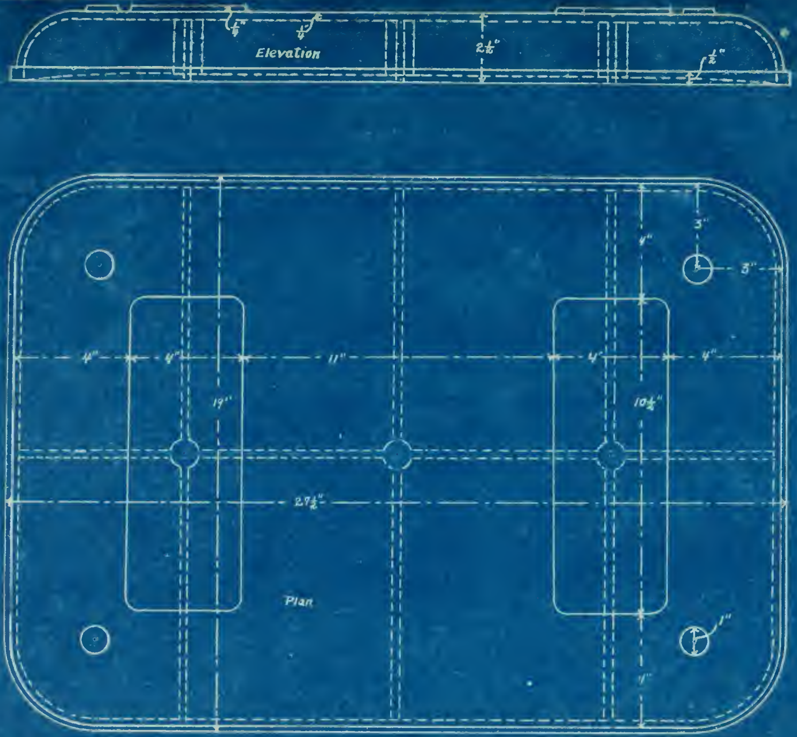
the brushes. There is a description of a method used by a Frenchman in the Soc. Int. Elect., (July 1904), I did not have the article but only an abstract of it, which was not absolutely clear on all points.

The method employed was as follows. The current was to be determined by measuring the drop over a portion of the armature winding not in a magnetic field and from the resistance of that to calculate the current flowing in the conductor. The drop in the conductor which would be very small was to be measured by means of a condenser and a balistic galvanometer. He had a special contact makerwhich was fastened to the shaft of the armature, which would for part of the revolution would charge the condenser over the section of the armature and then for the rest of the revolution would discharge the condenser through the galvanometer. The galvanometer and contact maker could be calibrated by known potentials, and from this calibration the potential of the condenser at the begining of the discharge could be determined. The pressure to which the condenser was charged would depend upon the pressure impressed upon the condenser just at the last instant of charge. The contacts of the contact maker were so arranged that the point of charge of the condenser could be changed so that the drop over the section of the armature conductor could be measured with the conductor in any position with reguards to the fields of the machine. In this way the current in the armature could be measured for all positions of the conductor and the form of the current save plotted. The chief trouble with this method is with the contact maker.

Another man in the Electrical World and Engineer (Aug. 1904) describes a method of measuring the difference of potential of different parts of the brush and the commutator and thus obtaining the current density in different parts of the brush at the point when it short circuited the coils. This thew

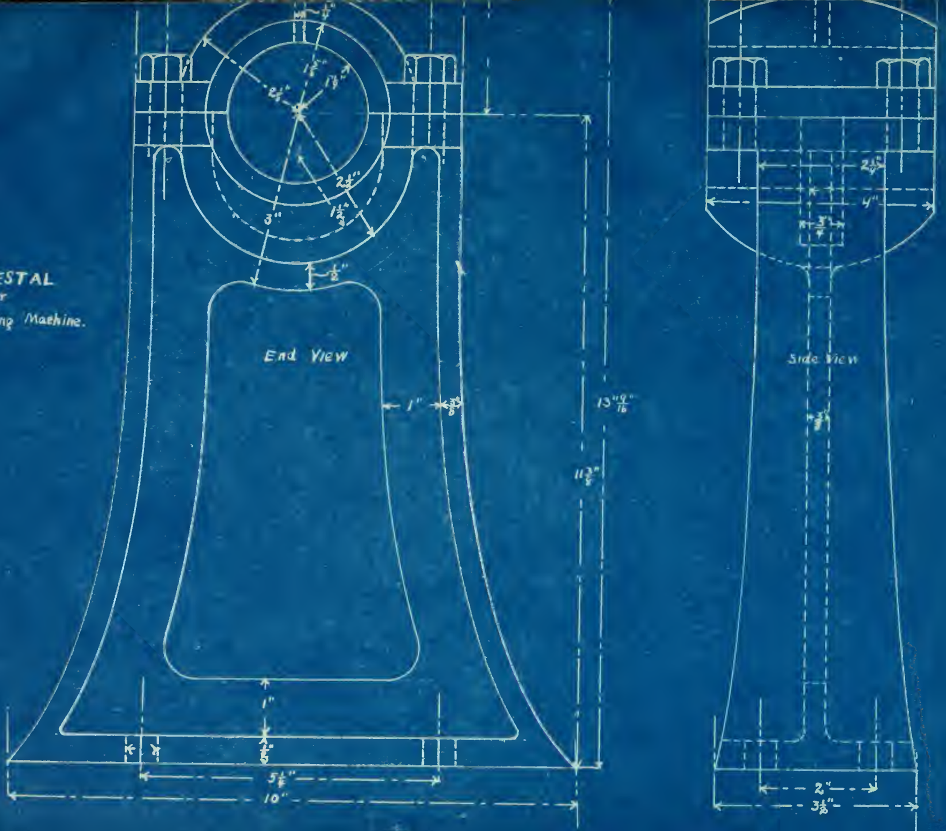
so light on the subject.

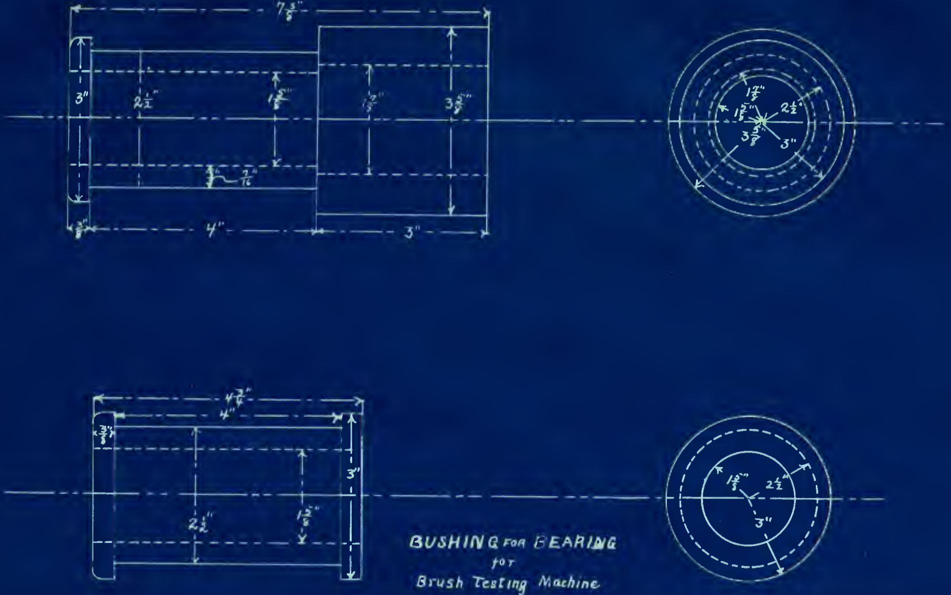
In searching for a method If followed to some extent the French man and attempted to find thecurrent in the coil by the fall of potential method Instead of using the drop ober that part of the coil which was not in the magnetic field I used the whole of a coil, and in order to overcome the effect of the field in which the coil rotated I commected a auxiliary wire to one end of the coil and then ran the wire in the slot with the coil so that it would cut the same field as the coil. The drop in potential or the potential difference between this auxiliary wire and the other end of the coil would be the drop in the coil due to the current in it, because the two wires cut the same field at the same rate and the e.m.f. generated in them is equal and op oposite. The auxilliary wire and the end of the coil are connected to rings from which current is taken by two brushes . This method depends principly upon the contact of the brushes and the rings. An oscillograph is connected to the brushes and the wave form of thecurrent wave can be photographed. The principle difficulty will be found in obtaining good brush contact. The rings must be true and the brushes made of laminated copper and I would suggest that more than one pair of brushes be used. I think that it would be well to provide some method of cleaning the contact rings. In the ballistic and condenser method brushes and petrol were used to clean the contact maker.



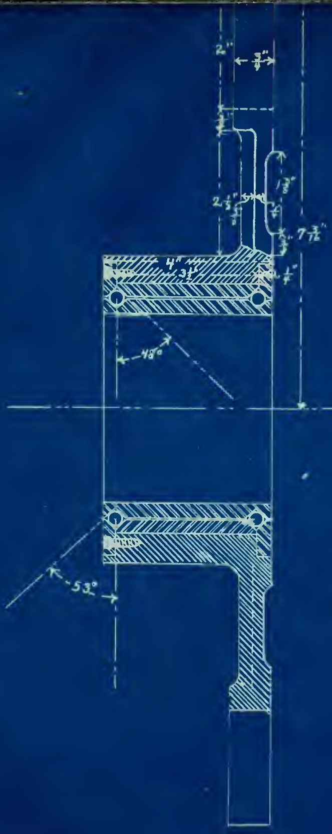
BED PLATE
of
BRUSH TESTER

PEDESTAL
for
Brush Testing Machine.

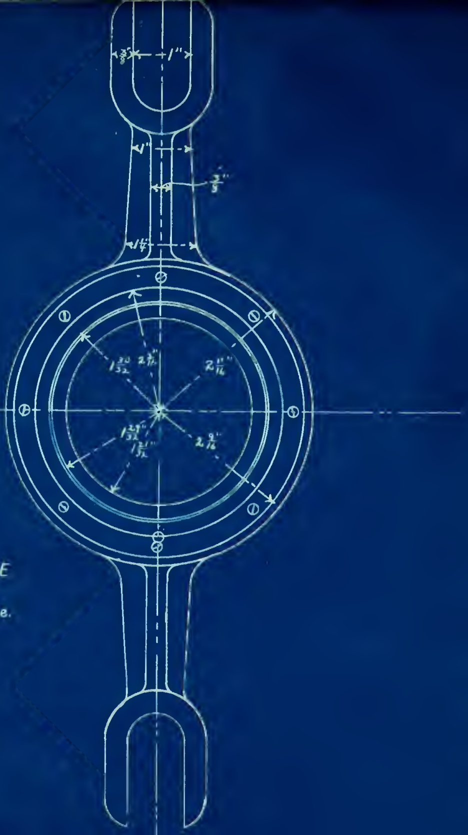


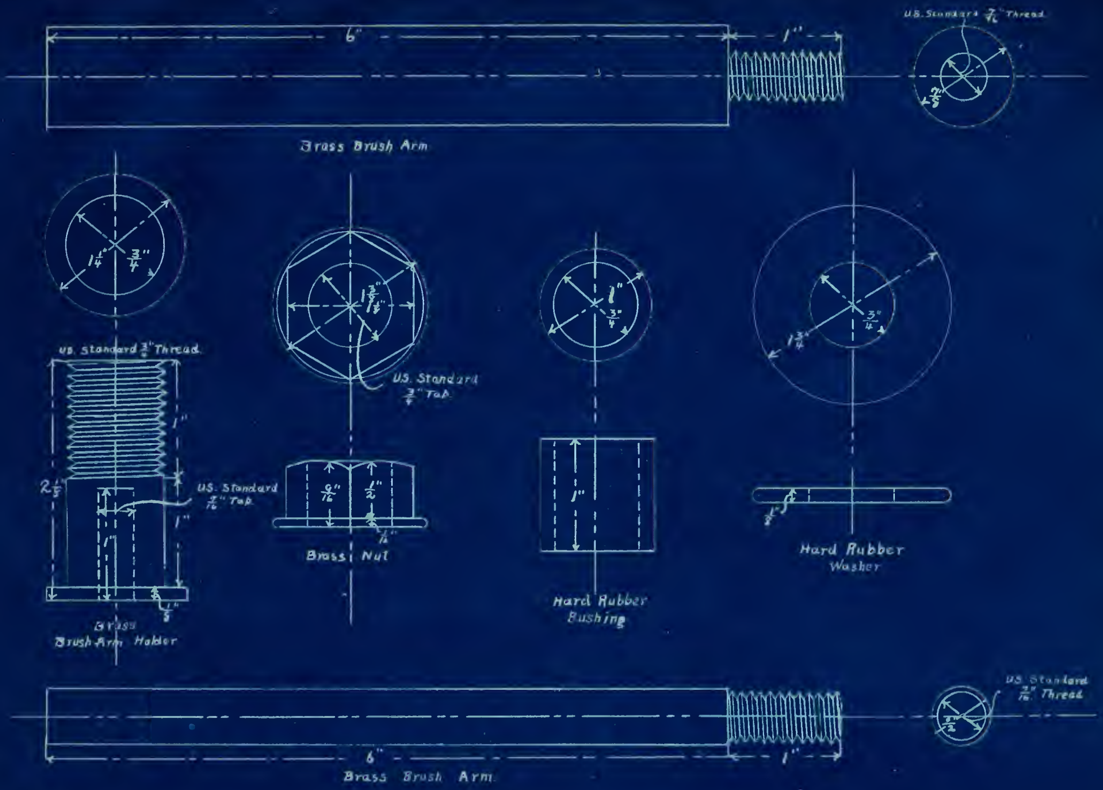


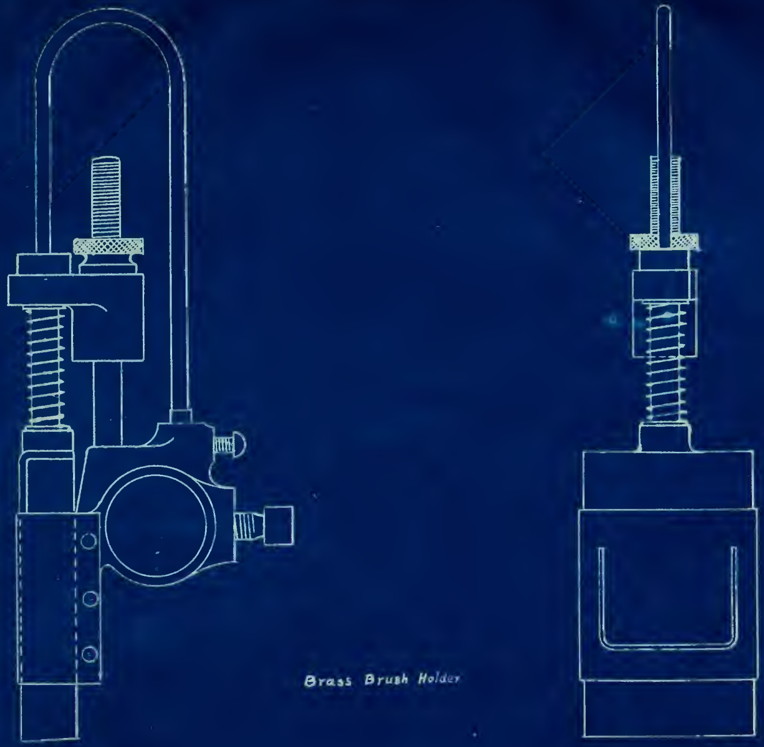
BUSHING FOR BEARING
for
Brush Testing Machine



BRUSH SPIDER
and
BALL BEARING RACE
for
Brush Testing Machine.




6"
1"
U.S. Standard 7/16" Thread
7/8"
Brass Brush Arm
1 1/4"
3/4"
U.S. Standard 3/4" Thread
1"
2 1/8"
U.S. Standard 7/16" Tap
1"
1"
1/8"
Brass
Brush Arm Holder
1 3/8"
1 1/4"
U.S. Standard
3/4" Tap
9/16"
1/2"
1/16"
Brass Nut
1"
3/4"
1"
Hard Rubber
Bushing
3/4"
1 3/4"
1/8"
Hard Rubber
Washer
U.S. Standard
7/16" Thread
1/2"
6"
1"
Brass Brush Arm



Brass Brush Holder